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Original Article

AREA, PRODUCTION AND PRODUCTIVITY FORECASTS OF RICE IN CHHATTISGARH PLAINS AGRO-CLIMATIC ZONE USING R-BASED-ARIMA

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ABSTRACT

The Chhattisgarh Plain is one of the most important ago-climatic zone of the State of Chhattisgarh. It is the highest rice producing region in the State. Therefore, the forecast of the area, production and productivity of rice in Chhattisgarh Plains over future period is of great concern to the planners of the State. So, the present study aims at studying the patterns of area, production and productivity of rice crop for Chhattisgarh Plains over a time series from 1980 to 2015 and their forecasts for the next five years using ARIMA and double exponential methods. This study used the libraries for forecast developed across the globally famous statistical software environment "R: The R Project for Statistical Computing" available at www.r-project.org. Some good models were developed for areas, production and productivity wherever model diagnostics were found to be good. A summary of Good fitted forecast models have been appended. Finally, the forecasts based on these good models have been made for the future periods from 2015-16 to 2019-20.

KEYWORDS: Chhattisgarh Plains, R, AR, MA, ARMA, ARIMA, ARIMA(p, d, q), DASC, Forecasting & CI80% & CI95%

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INTRODUCTION

The State of Chhattisgarh was created on November 1, 2000 as the 26th State of Indian Union by incorporating 16 districts of undivided eastern Madhya Pradesh. It shares its borders with six states of the country - Orissa in the east, Jharkhand in the north-east, Madhya Pradesh in the west and north-west, Uttar Pradesh in the north, Maharashtra in the south-west and Andhra Pradesh in the south and south-east. With a geographical area of 137.90 lakh ha (www.agridept.cg.gov.in), Chhattisgarh is the tenth largest State (https://en.wikipedia.org) in India, contributing about 2.97 per cent of the total annual food grains production in India (DASC, 2012-13). The State has a net sown area 47.75 lakh ha, cropping intensity 138 percentand forest coverage of 63.53 lakh ha. The State of Chhattisgarh comprises of three major agro-climatic zones, for which the agricultural scenario are quite different. These zones are respectively, the Chhattisgarh Plains, the Northern Hills and the Bastar Plateau. Among these, the Chhattisgarh Plain is the most important, in the sense that it is the highest crop producing region of the State, out of which rice crop is most prominent. Therefore, the forecast of the area, production and productivity of rice in Chhattisgarh Plains over future period is of great concern to the planners of the State. Hence, the present study aims at studying the patterns of area, production and productivity of rice crop for Chhattisgarh Plains over a time series from 1980 to 2015 and their forecasts for the next five years using ARIMAand double exponentialmethods. As the

Chhattisgarh Plains comprises of districts - Raipur, Bilaspur, Durg, Janjgir, Korba, Mahasamund, Balod, Balodabajar, Bemetara, Dhamatari, Gariaband, Kawardha, Mungeli, Raigarh, Rajnandgaon, this study speaks about the overall performance of all these districts together, in terms of their overall patterns and changes in area, production and productivity of rice crop.

METHODS

The present study utilizes a relational database created in the Department of Agricultural Statistics and Social Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, on the basis of data acquired from www.agridept.cg.gov.in and Anonymous (1981-1998).The detailed methodologies adopted in the present investigation are presented in the following sub-heads.

ARIMA MODEL

In time series analyses, an autoregressive integrated moving average (ARIMA) model is a generalization of an autoregressive moving average (ARMA) model, Anonymous (2016). These models are fitted to time series data either to better understand the data or to predict future points in the timeseries (forecasting). They are applied in some cases where data show evidence of non-stationary and where an initial differencing step (corresponding to the "integrated" part of the model) can be applied to reduce the non-stationary. Thus, the autoregressive (AR) component of the ARIMAmodel is a representation of a type of random process representing certain time-varying processes, economical phenomenon of the nature, etc. It specifies that the output variable depending linearly on its own previous values and on a stochastic term. This AR (p), an autoregressive model of order p, can be defined as,

$$Y_t = \mu + \sum_{i=1}^{p} \Phi_i Y_{t-i} + \mathcal{E}_t \tag{1}$$

Where, $\Phi_1, \ldots . \Phi_p$ are the parameters of the model, μ is a constant, and $\mathcal{E}_t$ is stochastic white noise.

The second component of ARIMA is Moving-Average (MA) model. The general MA process of order q can be defined as,

$$Y_t = \mu + \mathcal{E}_t + \Theta_1 \mathcal{E}_{t-1} + \cdots + \Theta_q \mathcal{E}_{t-q} \tag{2}$$

Where, μ is the mean of series, the $\Theta_1, \ldots, \Theta_q$ are the parameters of the model and the $\mathcal{E}_t, \mathcal{E}_{t-1}, \ldots, \mathcal{E}_{t-q}$are the

stochastic noise error terms. The value of q is called the order of the MA model.

Now, combining the AR process with the MA process and integrating, with differencing step, to remove non-stationarity from the non-seasonal time series, the ARIMA is generally denoted by ARIMA (p, d, q), where parameters p, d, and q are non-negative integers, p being the order of the autoregressive model, d being the degree of differencing, and q being the order of the moving-average model. In other words, ARIMA (p, d, q), is an autoregressive integrated moving average time series.

Thus, the ARIMA (p, d, and q) model, (Qbal, N. etal. 2005) can be represented by the following general forecasting equation:

=μ+$_{t-i}$ +$_{t-j}$ + (3)

Or,

=μ+$_{t-i}$ +$_{t-j}$ (4)

DOUBLE EXPONENTIAL SMOOTHING MODEL

The double exponential smoothing is best applied to time series that exhibit prevalent additive (non-exponential) trend, but do not exhibit seasonality. (Prajakta S. (2004)). The recursive form of the Holt's double exponential smoothing equation is expressed as follows:

$\hat{F}_t$(m) = S_t + m × b_t

S_t =αY_t+ (1-α)($S_{t-1} + b_{t-1}$)

$b_t = \beta(S_t - S_{t-1})$ + (1-β)b_t

Where

-is the value of the time series at time t;

-is a smoothed estimate of the value of the time series Y at the end of period t;

-is a smoothed estimate of average growth rate at the end of period t.

α-is the level smoothing coefficient.

β -is the trend smoothing coefficient.

-is the m-step-ahead forecast values for Y from time t.

The estimates and forecasts for above mentioned models have been computed based on the libraries developed in the globally famous statistical software environment "R: The R Project for Statistical Computing" available at www.r-project.org. The authors have used the methods relevant to these as illustrated in Coghlan, A. (2014, 2017).

RESULT AND DISCUSSIONS

Based on the methods elucidated above, some good models have been estimated using double exponential and ARIMA models as listed in following Table 1.1, for which predictions were made:

Table 1.1: Synopsis and Evaluation of fitted models based on (i) Model-1: Double exponential model with parameters α, β, a, b and (ii) Model-2: ARIMA model with parameters ACF, P-value, AIC, BIC, σ^2; and respective diagnostic plots with confidence intervals.

Table

Crop	Variables	Region	Model Adequacy
Rice	Area	Chhattisgarh Plains	Model-1:Good fit
			Model-2:Good fit
	Production	Chhattisgarh Plains	Model-1:Good fit
			Model-2:Good fit
	Productivity	Chhattisgarh Plains	Model-1:Good fit

			Model-2:Good fit

So, using the good models as indicated in Table 1.1 above, the estimated parameters of forecasting models for area, production and productivity under rice crop for Chhattisgarh Plains for the period 1980-81 to 2014-15 have been presented along with the relevant forecasts and their confidence intervals in Figure A.1 to Figure A.6in the Appendix-A, respectively for double exponential smoothing forecast as well as for ARIMA forecast. These are followed by respective graphs for plots of model diagnostics of (a) observed *vs.* fitted and (b) double exponential smoothing forecast, (c) Time Series (d) ARIMA Diagnostic Graph and (e) ARIMA Forecasting etc.

The figures from Figure A.1 to Figures A. 6 in the Appendix-A, can be compared for various estimates of parameters for levels, trends and seasons of area, production and productivity of Chhattisgarh Plains under rice crop. Thus, from Figures A. 1 in the Appendix-A, left side table, for area of rice it is found that the α coefficient of double exponential model is moderate (0.5, equal to maximum 1), therefore the level of this model can be said to depend moderately on the recent observations than the past observations during the period of study from 1980-81 to 2014-15, with the start of the level at 2968.20, whereas the value of β-coefficient is very low (0.04, close to zero) indicating that there is almost least trend in the double exponential model estimate, with the start of the trend at a low value of 22.55, for the period 1980-81 to 2014-15. Secondly, from Figures A. 2, left side graph, it is clear that the autocorrelation (i.e. ACF) is zero because p-value > 0.70, which is also reflected from Figures A. 1, left side table, wherein it is further noted that the AIC value is 445.1 with variance of 14434, i.e., standard deviation of 120.14 thousand ha.. The forecast of the area under rice by double exponential model and ARIMA model are depicted in upper tables of Figures.A.1 and Figures A. 2 in the Appendix-A, respectively for 80% and 95% confidence intervals for five years from 2015-16 to 2019-2020. On perusing the tables of these figures, it may be concluded that forecasted area for the double exponential model is 2940.89 000’ha with approximate 80% confidence interval (CI80%) of (2600-3200) 000’ha and approximate 95% confidence interval (CI95%) of (2400-3300) 000’ha. On the other hand, the forecasted area for ARIMA model are in the range (from 2871.27 to 2922.92) 000’ha for all the five years from 2015-16 to 2019-2020 with CI80% values being in the range2600-3100000’ha and CI95% range 2500-3200000’ha. Clearly, the ARIMA estimates give lower confidence intervals with pointed better pointed forecast.

From Figures A. 3, left side table, for production of rice it is found that the α coefficient of double exponential model is moderate (0.64, equal to maximum 1), therefore the level of this model can be said to depend moderately on the recent observations than the past observations, with the start of the level at6014.4, whereas the value of β-coefficient is low (0.30) indicating that there is least trend in the double exponential model estimate, with the start of the trend at a value of 279.25, for the period 1980-81 to 2014-15. Secondly, from Figures A. 4 in the Appendix-A, left side graph, it is clear that the autocorrelation (i.e. ACF) is zero because p-value > 0.40, which is also reflected from Figures A. 1, left side table, wherein it is further noted that the AIC value is 565.95 with variance of 515006, i.e., standard deviation of 717.6 000’tonnes. The forecast of production under rice by double exponential model and ARIMA model are depicted in upper tables of Figures A. 3 and Figures A. 4 in the Appendix-A, respectively for 80% and 95% confidence intervals for the five years from 2015-16 to 2019-2020. On perusing the tables of these figures it may be concluded that forecasted production for the double exponential model is 5788.33 000’tonnes with approximate 80% confidence interval (CI80%) of (4300-7200) 000’tonnes and approximate 95% confidence interval (CI95%) of (3500-8000) 000’tonnes. On the other hand, the forecasted production for ARIMA model are in the range (from 5569.3 to 5708.74) 000’tonnes for all the five years from

2015-16 to 2019-2020 with CI80% values being in the range (4000-7300) 000'tonnes and CI95% range (3200-8200) 000'tonnes. Evidently, the ARIMA estimates give better pointed forecastwith lower confidence intervals.

Next, from Figures A. 5 in the Appendix-A, left side table, for productivity of rice, the α coefficient of double exponential model is moderate (0.46, equal to maximum 1), so the level of the model depends moderately on the recent observations than the past observations, starting at 2023.1989, theβ-coefficient beinghigh (0.70) indicating high trend in the double exponential model estimate, with the intercept of 103.66, for the period 1980-81 to 2014-15. Secondly, from Figures A. 6 in the Appendix-A, left side graph, the autocorrelation (i.e. ACF) is zero because p-value > 0.60, which is also reflected from Figures.A.1, left side table, wherein it is further noted that the AIC value is 488.89 with variance of 53142, i.e., standard deviation of 230.52kg. The forecast of productivity under rice by double exponential model and ARIMA model are depicted in upper tables of Figures A. 5 and Figures A. 6 in the Appendix-A, respectively for 80% and 95% confidence intervals for the five years from 2015-16 to 2019-2020. On perusing the tables of these figures it is concluded that productivity for the double exponential model are forecasted in the range of (from 1732.465 to 1839.33) kg with approximate CI80% of (1300-2200) kg and CI95% of (1100-2500) kg. On the other hand, the forecasted productivity for ARIMA model are in the range (from 1828.29 to1888.45) kg for all the five years from 2015-16 to 2019-2020 with CI80% values being in the range (1400-2300) kg and CI95% range (1100-2600) kg. In comparison, the double exponential estimates give almost the same precision in terms of corresponding confidence intervals as of ARIMA estimates, so both types of estimates are equally efficient in the case of productivity forecast.

Finally, based on Figures A. 1-A. 6, a clear picture emerges in terms of a great diversification of area under rice to other crops from the year 1998-99 onwards upto 2010 in Chhattisgarh Plains, which is caused by the creation of State of Chhattisgarh when a great drive was undertaken by the then State Government. Due to these factors, the area and production of rice took a sudden dip in 1998-99 and then gradually rose onwards up to 2010, and thereafter rose even more steeplyfurther up to 2012-13 with a bit of moderation in 2014-15, indicating that the diversification of rice to other crops has shifted back to rice in the entire Chhattisgarh Plains. However, the productivity of ricemaintained a rising trend after a few years of stationarity following diversification of rice area to other crops in Chhattisgarh Plains, in 1998-99, possibly as a result of policy paralysis emerging out of shock due to above-said diversification.Despite these, the production of rice in Chhattisgarh Plains in 2014-15 has now crossed the peak of rice production compared to what it was just before the start of diversification, in 1998-99, of rice area to other crops in Chhattisgarh Plains.

CONCLUSIONS

It may be concluded from the present study that ARIMA models fitted uniformly better than the double exponential models, as depicted from Figures A. 1-A. 6 in the Appendix-A, for area, production and productivity of rice under Chhattisgarh Plains, in terms of all the standard diagnostics' estimates like AIC, BIC, p-values, confidence intervals (CIs), autocorrelation functions (ACFs) on the one hand; and graphical diagnostics on the other hand, like observed vs. fitted graphs and ARIMA ACF graphs. It is further concluded that the area and production of rice took a sudden dip in 1998-99 indicating a great deal of diversification of rice area to other crops. However, both parameters gradually rose onwards but rose even more steeply from 2010 onwards up to 2012-13 and then got moderated in 2014-15. Yet, the productivity maintained a rising trend, after a few years of stationarity following diversification of rice area to other crops in Chhattisgarh Plains in 1998-99, possibly as a result of policy paralysis emerging out of shock due to above-said diversification. Despite these, the production of rice in Chhattisgarh Plains in 2014-15 has now crossed the peak of rice

production compared to what it was just before the start of diversification, in 1998-99, of rice area to other crops in Chhattisgarh Plains.

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APPENDIX-A

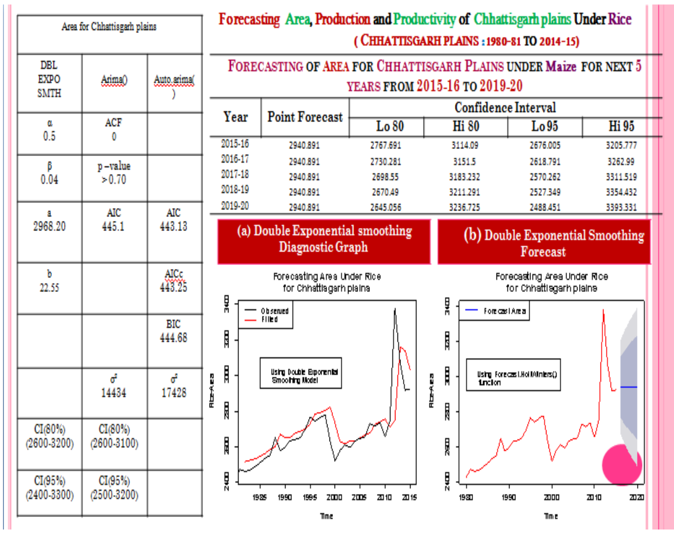

Figure A 1: Estimates of Double Exponential, ARIMA Models and Forecast of the Former, for Area of Chhattisgarh Plains UNDER Rice for 1980-81 to 2014-15 along with Diagnostic Graphs (a)Observed vs. Fitted and (b) Double Exponential Smoothing Forecast

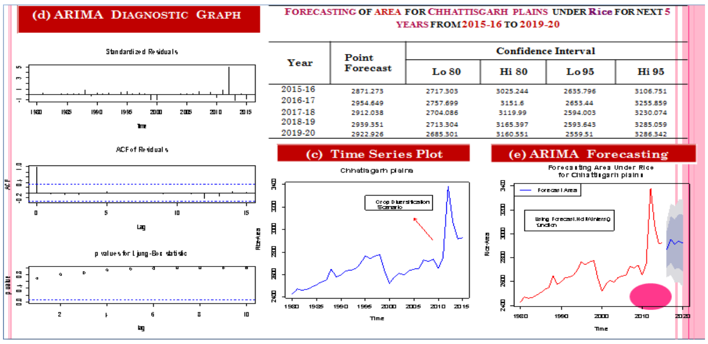

Figure A.2: Forecast of the ARIMA Model, for Area of Chhattisgarh Plains Under Rice for 1980-81 to 2014-15 along with Diagnostic Graphs (c) Time Series, (d) ARIMA Diagnostic Graph and (e) ARIMA Forecasting

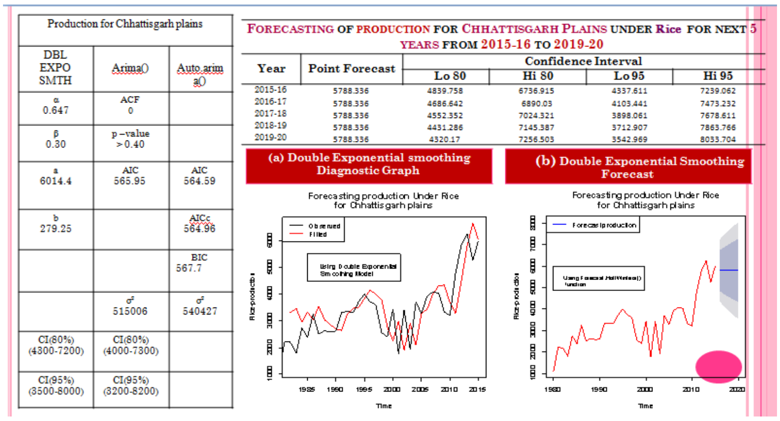

Figure A.3: Estimates of Double Exponential, ARIMA Models and Forecast of the Former, for Production of Chhattisgarh Plains under Rice for 1980-81 to 2014-15 along with Diagnostic Graphs (a) Observed Vs Fitted and (b) Double Exponential Smoothing Forecast

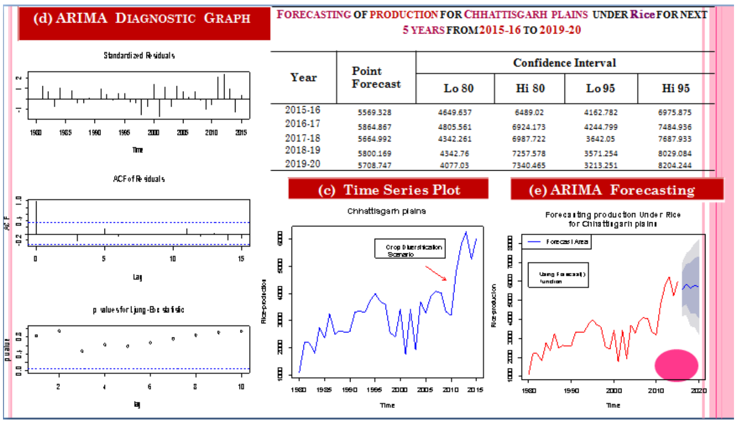

Figure A.4: Forecast of the ARIMA Model, for Production of Chhattisgarh Plains Under Rice for 1980-81 to 2014-15 along with Diagnostic Graphs (c) Time Series, (d) ARIMA Diagnostic Graph and (e) ARIMA Forecasting.

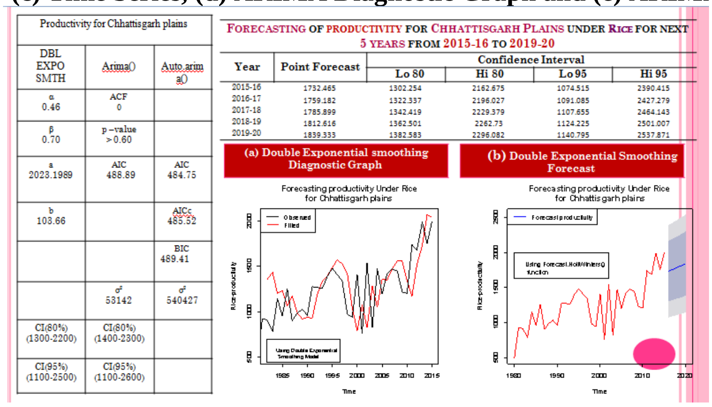

Figure A.5: Estimates of Double Exponential, ARIMA Models and Forecast of the Former, for Productivity of Chhattisgarh plains Under Rice for 1980-81 to 2014-15 along with Diagnostic Graphs (a) Observed Vs. Fitted and (b) Double Exponential Smoothing Forecast

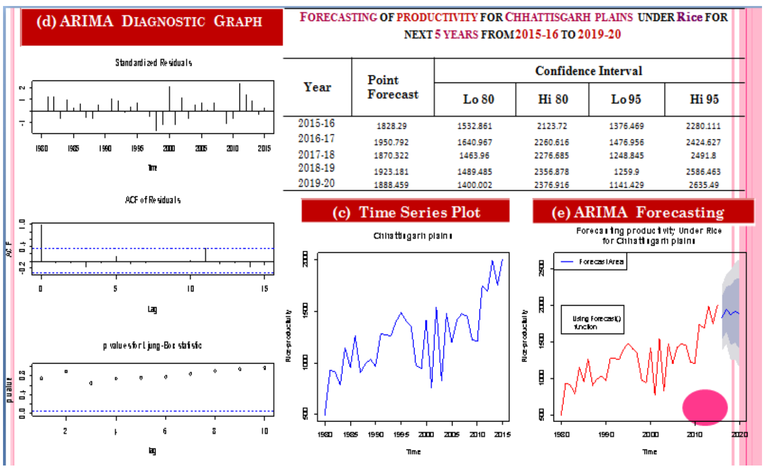

Figure A.6: Forecast of the ARIMA Model, for Productivity of Chhattisgarh Plains Under Rice for 1980-81 to 2014-15 along with Diagnostic Graphs (c) Time Series, (d) ARIMA Diagnostic Graph and (e) ARIMA Forecasting